BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Orbital Workshop Environmental Control System Case 620

DATE: March 11, 1968

FROM: D. J. Belz

ABSTRACT

This memorandum provides a brief description of the OWS ECS and an assessment of its capabilities. It is concluded that:

(a) An increase in the degree of active control that can be exercised over the Workshop's thermal environment is desirable; studies directed toward integrating the Workshop's thermal control system with the active heat rejection capability of the MDA are in progress at MSFC.

(b) The current OWS ECS cannot prevent local condensation of atmospheric water vapor, particularly around hull penetrations having exceptionally good thermal coupling to cold portions of the OWS exterior. MSFC's analyses, however, indicate that condensation is not likely to occur over large areas, nor is fog at all likely to form; these analyses also indicate that the minimum absolute humidity required for crew comfort will be maintained.

(c) Avoidance of uncontrolled condensation in the Workshop requires adequate moisture removal capability in the Airlock ECS. Design studies at MSC and MSFC are in progress to assure that a sufficient number of condensing heat exchangers are incorporated into the Airlock design.

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MEMORANDUM FOR FILE

1.0 INTRODUCTION

The Orbital Workshop (OWS) environmental control system (ECS) is designed to perform the following functions: control of internal temperatures to provide a thermally comfortable environment for the crew; prevention of uncontrolled condensation of water vapor; and maintenance of cabin-atmospheric gas velocity consistent with crew comfort,and adequate to permit centralized removal of atmospheric contaminants such as carbon dioxide. Atmospheric purification and humidity control for the entire Cluster, including the Orbital Workshop, is provided by the Airlock's environmental control system. This memorandum provides a brief description of the OWS ECS and an assessment of its capabilities.

2.0 OWS THERMAL CONTROL

The current Workshop design achieves a thermal balance primarily by passive means augmented by an active system of thermal ducts and heaters within the vehicle. Passive control of the net heat rejected to space through the Workshop's cylindrical walls is achieved by selecting the absorptivities and emissivities of thermal control coatings on the outer face of the SIVB shell and both faces of the standoff meteoriod bumper.

The inner face of the SIVB shell is lined with sixteen longitudinal ducts through which cabin "air" is forced by eight independently controlled fans. Increasing the "air" flow through a duct decreases the resistance to heat flow into or out of the Workshop across that duct. Each fan has three speeds: off; low (125 cfm); and high ($\sim$ 180 cfm). A fan control logic system activates fans on the "cold" side of the Workshop to reject heat, and may deactivate fans on the warm side to reduce absorption of heat from external sources if interior temperatures tend to rise above nominal levels. Similarly, control logic is provided to deactivate fans on the cold side of the Workshop and, if required, to activate fans on the warm side to reduce the net heat rejected to space if temperatures tend to fall below nominal levels.

The overall design is established such that maximum acceptable internal temperatures occur if the maximum anticipated incident thermal radiation from Earth and Sun is applied to the Workshop simultaneously along with the maximum anticipated internal heat generated within the vehicle. This establishes the required emissive properties of the thermal control coatings mentioned previously; if the Workshop is then considered to be exposed to the minimum incident heat flux in combination with the minimum anticipated internal heat generation, the resulting vehicle temperatures can be calculated. If these temperatures are less than minimum acceptable temperatures, additional internal heat is supplied by electrical heaters located in plenums at one end of the thermal control ducts.

Upper and lower bounds on acceptable "air" and surface temperatures are determined by crew thermal comfort limits which require: (a) no more than a ± 65 Btu variation from normal heat storage within the body of an individual crewman; (b)absolute "air" temperature limits of $\sim 50^{\circ}F$ to $100^{\circ}F$; (c) absolute surface temperature limits of $55^{\circ}F$ to $105^{\circ}F$; (d) mean radiant temperature limits of 60° to $100^{\circ}F$.The requirement to avoid condensation implies no less than a $46^{\circ}F$ temperature at the minimum acceptable absolute humidity level (8 mmHg partial pressure of water vapor).

In addition to the OWS thermal control system described above, it should be noted that metabolic heat transferred to the Workshop atmosphere as latent heat carried by water vapor from the crew is removed from the atmosphere in the Airlock ECS's condensing heat exchangers as a "by-product" of humidity control.

Current analyses indicate that the baseline thermal control system described above is capable of meeting crew thermal comfort requirements. A modification to the present thermal control system is, however, under study at MSFC: The objective of the modification is to increase the degree of active thermal control which can be exercised over the OWS environment. The system under study would apply low emissive ($\varepsilon \sim 0.05$) thermal coatings on the outside of the SIVB shell and inside of the meteoriod bumper adjacent to one or more of the existing thermal control ducts. This would decrease the OWS capability to absorb or reject heat by radiation/conduction through the walls, thereby decreasing the vehicles sensitivity to the external environment. It also requires additional capability for heat removal from the OWS interior; this would be accomplished by circulating OWS "air" to the MDA where existing cabin heat exchangers are available to remove heat via liquid coolant lines to the existing MDA radiators for rejection to space.

3.0 PREVENTION OF CONDENSATION IN THE OWS

Uncontrolled condensation in the Workshop, if it occurred, could conceivably reduce the partial pressure of water vapor in the "air" below the 8 mmHg required to prevent drying of the crew's mucous membranes; accumulations of liquid water would provide a congenial environment for the growth of microorganisms and in general create an unpleasant, dank environment.

Prevention of uncontrolled condensation is largely a matter of temperature control, provided the Airlock's condensing heat exchangers are capable of removing water vapor from the atmosphere as required. At the minimum acceptable humidity level of 8 mmHg the dew point is 46°F; with that minimum humidity level, fog will begin to form in the Workshop if the local air temperature is reduced below 46°F and dew will form on surfaces having temperatures less than 46°F. Current analyses of humidity levels in the Workshop performed by MSFC indicate that condensation is not likely to occur over large surface areas in the Workshop, nor is fog at all likely to form. Local condensation may occur as it has occurred in flights of previous spacecraft.

Available analyses are not sufficiently detailed to predict the extent of such local condensation; MSFC is, however, confident that at least an 8 mmHg partial pressure of water vapor will be maintained after the start-up transient of initially dry "air" is overcome. If the modified thermal control system currently under study is adopted as a new baseline design, currently budgeted heater power could provide higher wall temperatures than the current baseline and thus a further reduction in the likelihood of uncontrolled condensation. Design studies are in progress at both MSC and MSFC to ascertain the need for an additional condensing heat exchanger in the Airlock ECS to insure ample humidity control capability.

4.0 VENTILATION

Humidity and atmospheric contaminant control for the OWS are accomplished in the Airlock ECS; maintenance of the required "air" circulation from Workshop to Airlock and within the Workshop itself is accomplished by the OWS ECS.

Air motion in the Workshop is maintained primarily by the eight thermal control fans described previously, nine "cabin" fans with variable diffusers, and two exhaust fans located in the food and waste management compartments. "Air" flow through the crew quarters is facilitated by the use of perforated floors, the perforations being 2.5" in diameter and spaced 11 inches between centers. "Fresh air" returned from the Airlock ECS is mixed with "air" circulating within the OWS in plenums to obtain a uniform mixture. "Air" flow through the food and waste management areas is maintained at 50 cfm.*

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* cfm = cubic feet per minute.

Crew comfort criteria being employed in the design require "air" velocities not less than 15 ft/min. nor greater than 100 ft/min. The lower bound on air velocity is intended to avoid dead "air" pockets and large changes in convective heat loss from crewmen resulting from body movements; the upper bound is intended to avoid the subjective sensation of a "drafty" environment and to prevent uncomfortable local skin temperatures.

5.0 CONCLUSION

Available studies of the Orbital Workshop's current baseline thermal control system indicate that the system is capable of meeting the thermal comfort criteria established by MSC's Medical Research and Operations Directorate. This system is, however, inherently sensitive to departures from the vehicles nominal orientation or attitude in space since it is primarily a passive system. It is desirable to increase the degree of active thermal control that can be exercised over the Workshop's environment; studies to decrease the Workshop's sensivity to the external thermal environment and to increase the vehicle's tolerance of variations in internal heat generation are in progress at MSFC. The approach taken is to integrate the Workshop's thermal control with the active heat rejection capability of the MDA.

The current OWS ECS cannot prevent condensation in local areas, particularly around hull penetrations having exceptionally good thermal coupling to cold portions of the OWS exterior. Current analyses, however, indicate that condensation is not likely to occur over large areas nor is fog at all likely to form. These analyses also indicate that the minimum absolute humidity required for crew comfort will be maintained. Avoidance of uncontrolled condensation in the Workshop requires adequate moisture removal capability in the Airlock ECS; design studies in MSC and MSFC are in progress to assure that a sufficient number of condensing heat exchangers are incorporated into the Airlock design.

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